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Reik et al.

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[54] **ASSEMBLY FOR TAKING UP AND COMPENSATING FOR TORQUE INDUCED SHOCKS**

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Related U.S. Application Data

[62] Division of application No. 08/292,772, Aug. 18, 1994, which is a division of application No. 07/627,551, Dec. 10, 1990, Pat. No. 5,374,218, which is a continuation of application No. 07/391,738, Aug. 8, 1989, abandoned, which is a continuation of application No. 07/111,401, Oct. 20, 1987, abandoned, which is a division of application No. 06/896,136, Aug. 12, 1986, Pat. No. 4,723,463, which is a continuation of application No. 06/669,770, Nov. 8, 1984, abandoned.

[30] **Foreign Application Priority Data**

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Mar. 5, 1984	[DE]	Germany	34 11 239

[51] **Int. Cl.**^{6} **F16D 3/14**
[52] **U.S. Cl.** **464/68**; 192/212
[58] **Field of Search** 464/66, 68, 64; 192/212, 213, 214; 74/574

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Attorney, Agent, or Firm—Darby & Darby

[57] **ABSTRACT**

A torsion damping assembly which is installed between the crankshaft of the engine and the input element of the change-speed transmission in a motor vehicle has two coaxial flywheels one of which is driven by the crankshaft and the other of which can transmit torque to the transmission in response to engagement of a friction clutch. The transmission of torque between the two flywheels takes place by way of a damper and a slip clutch which latter is effective only within a selected range of possible angular movements of the two flywheels relative to each other.

16 Claims, 4 Drawing Sheets

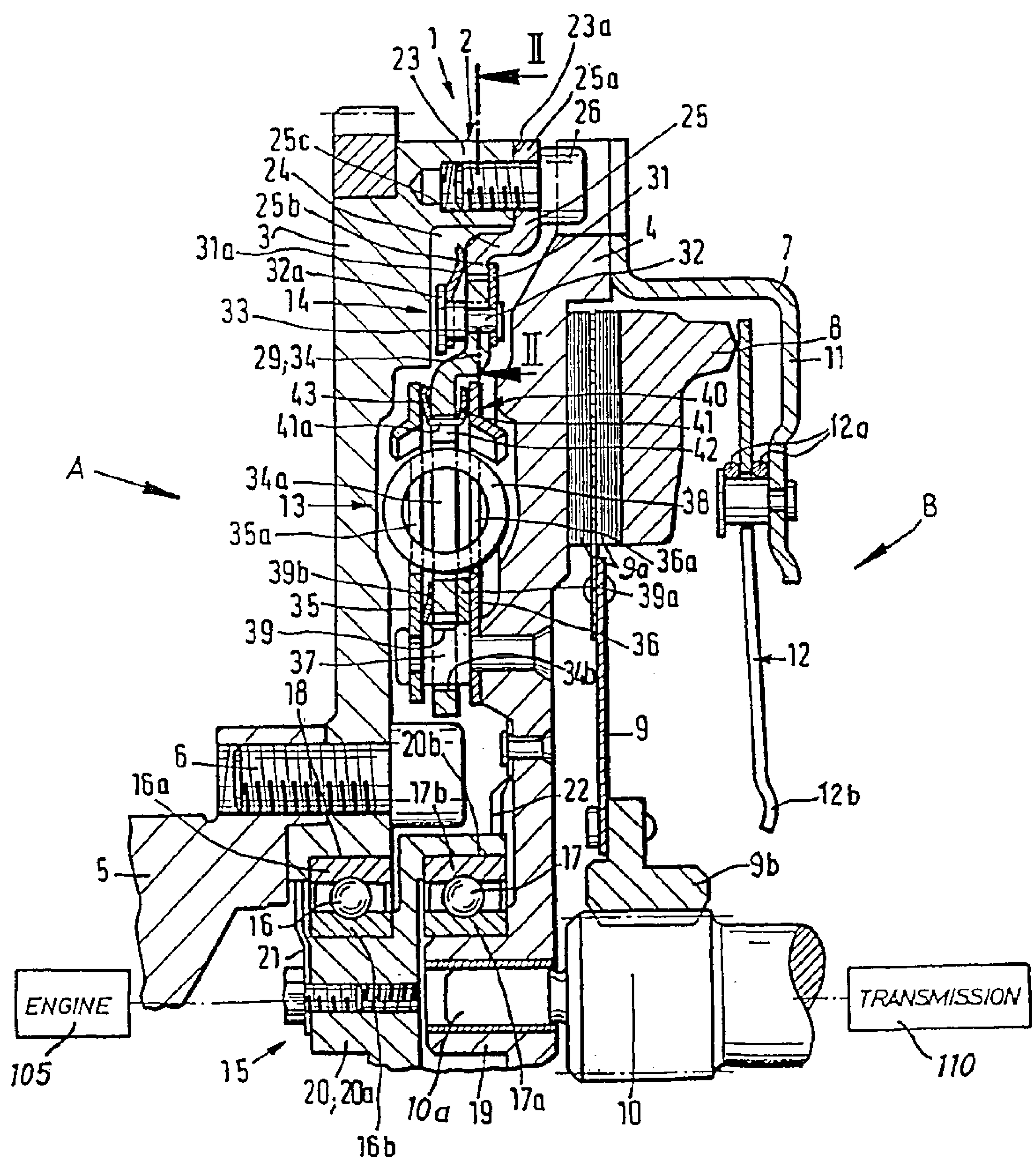
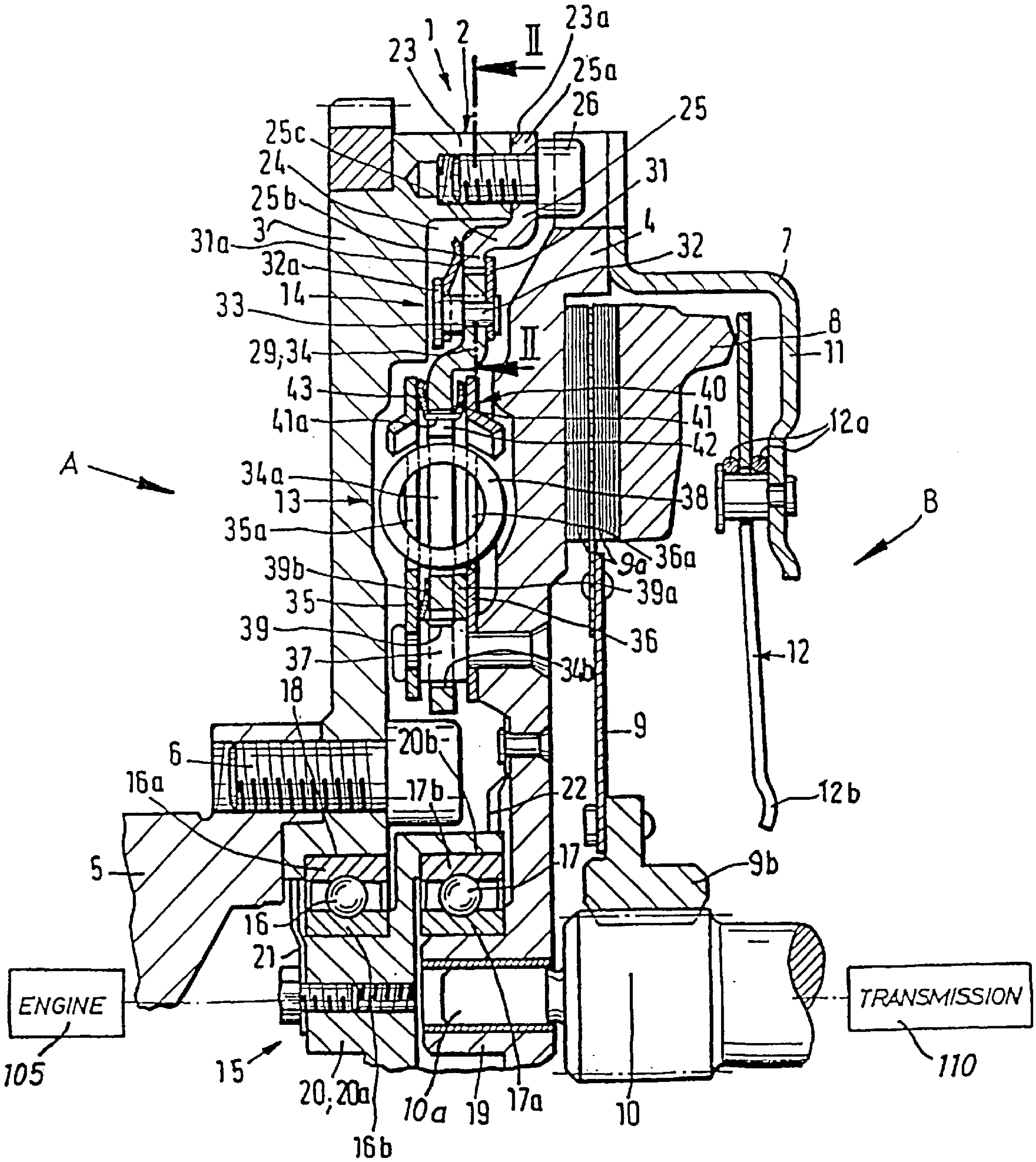


Fig.1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17b
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12b
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17a
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TRANSMISSION
110

Fig.2

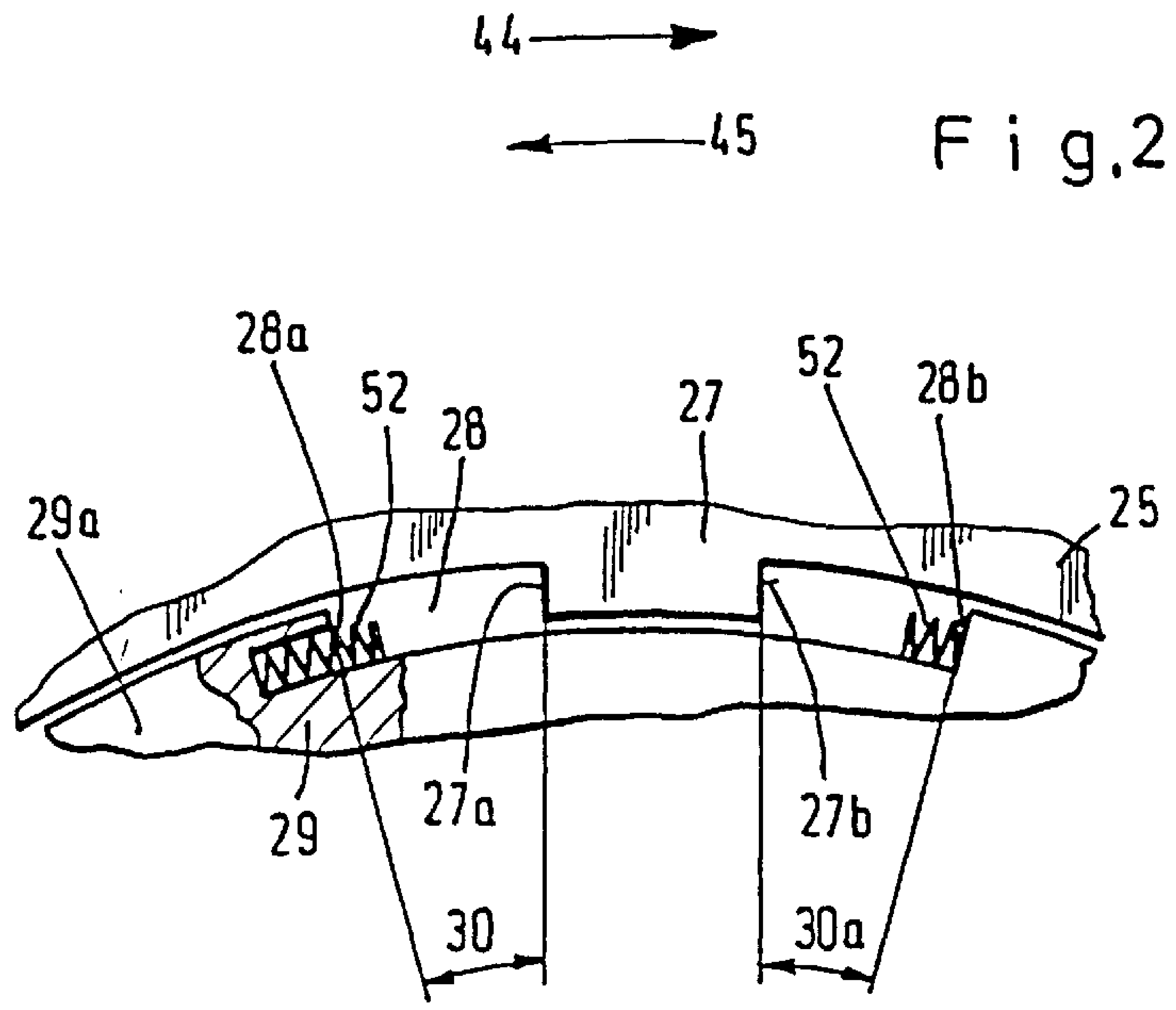
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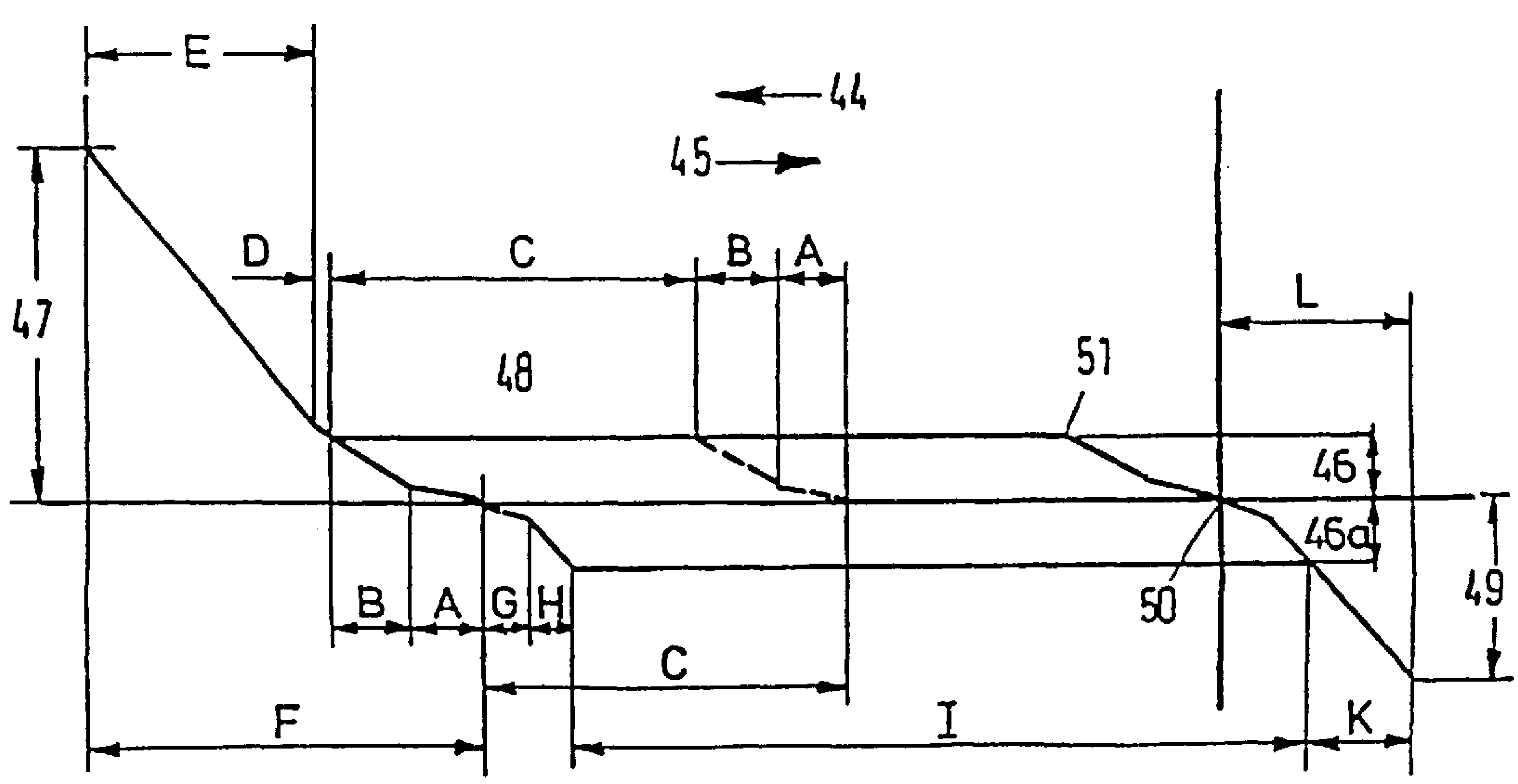
Fig.3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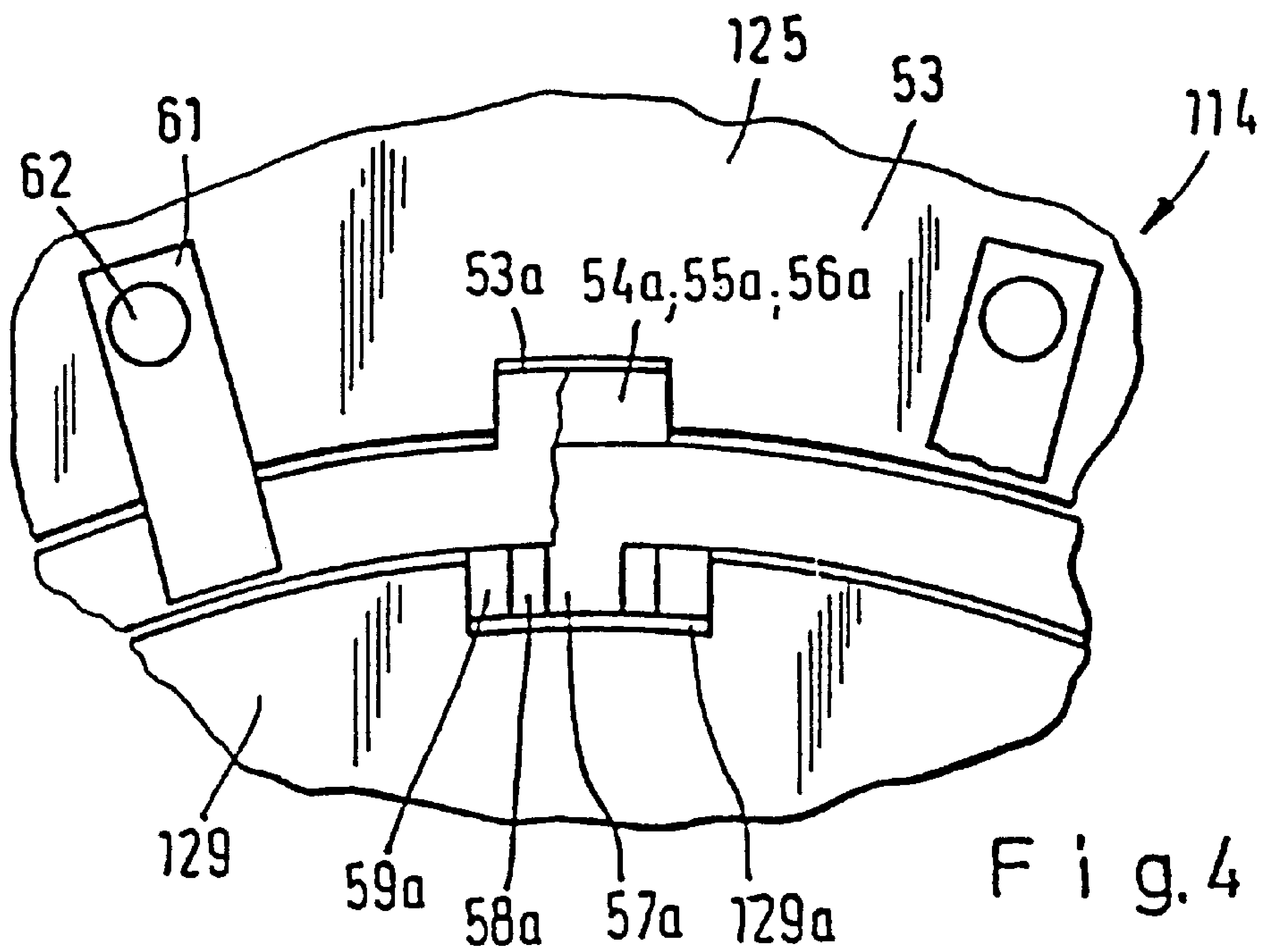
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58a
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129a

Fig.4

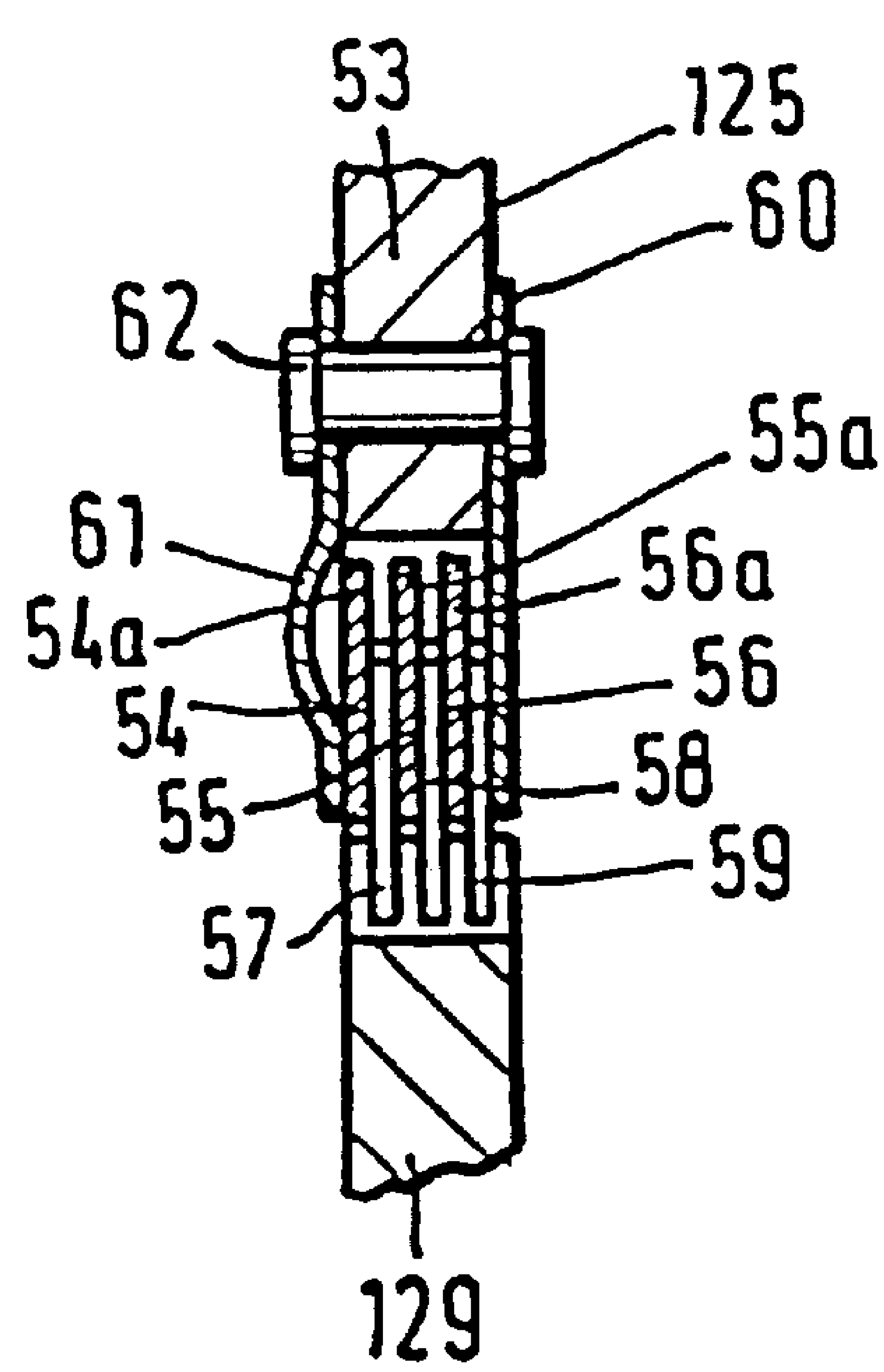
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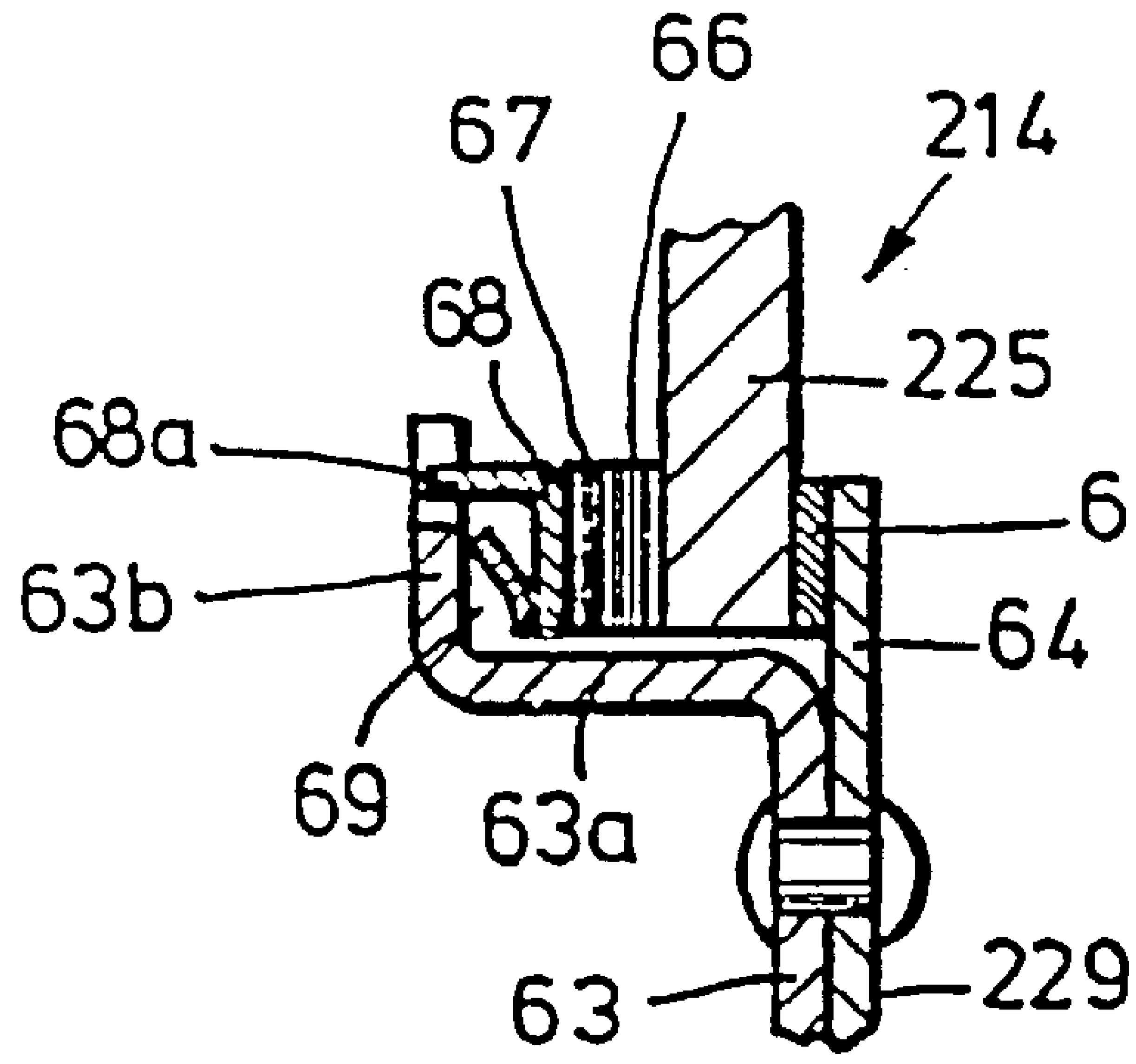
Fig.5

Fig.6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63a
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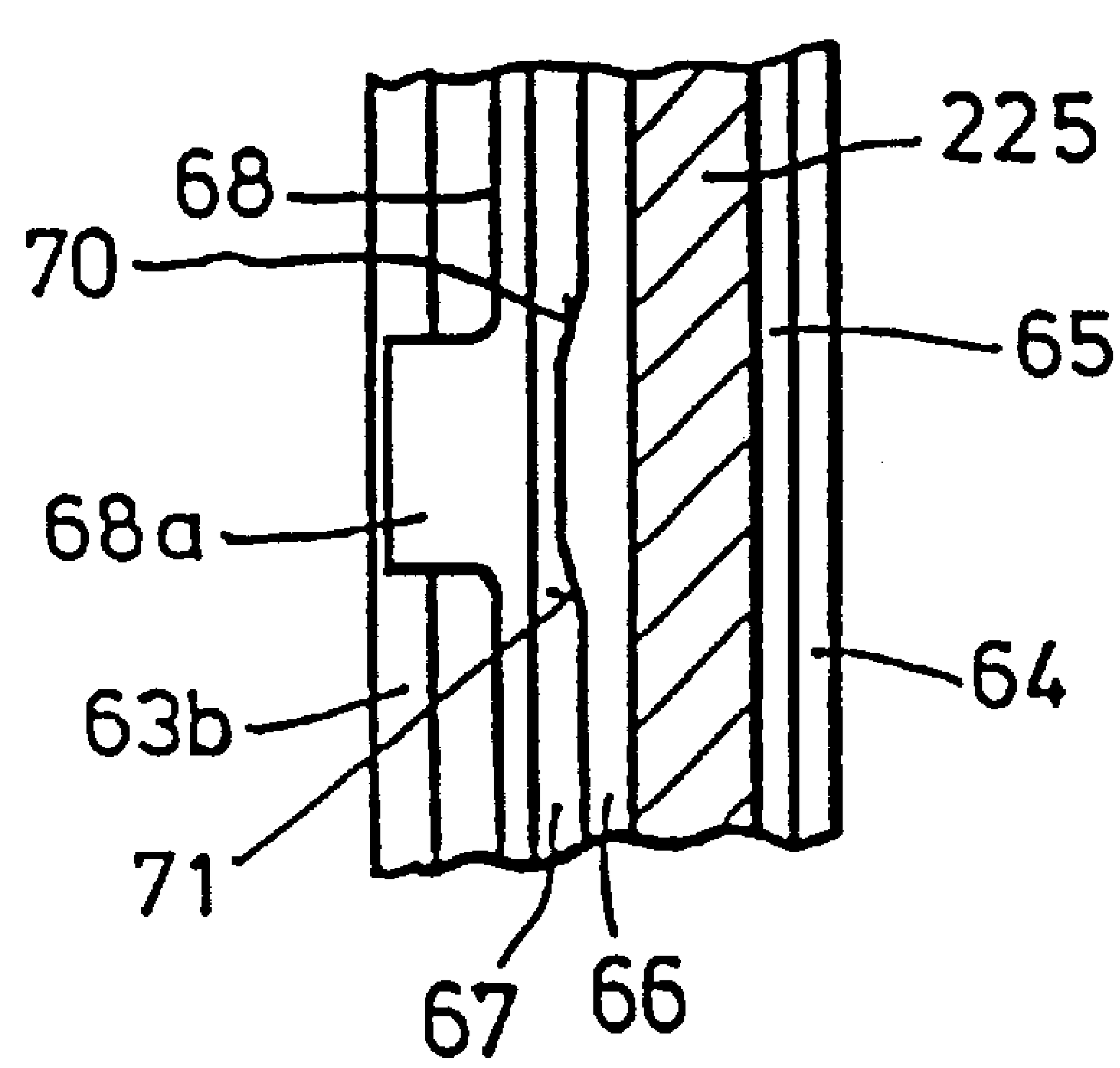
Fig.7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63b
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ASSEMBLY FOR TAKING UP AND COMPENSATING FOR TORQUE INDUCED SHOCKS

This is a division of pending application Ser. No. 08/292,772 filed Aug. 18, 1994, which is a division of Ser. No. 07/627,551 filed Dec. 10, 1990, now U.S. Pat. No. 5,374,218 granted Dec. 20, 1994, which is a continuation of Ser. No. 07/391,738 filed Aug. 8, 1989, now abandoned, which is a continuation of Ser. No. 07/111,401 filed Oct. 20, 1987, now abandoned, which is a division of Ser. No. 06/896,136 filed Aug. 12, 1986, now U.S. Pat. No. 4,723,463 granted Feb. 9, 1988, which is a continuation on Ser. No. 06/669,770 filed Nov. 8, 1984, now abandoned.

BACKGROUND OF THE INVENTION

The invention relates to improvements in assemblies which can be utilized to take up and to compensate for-shocks which develop as a result of fluctuations in the rotational speed of the output element of an internal combustion engine. More particularly, the invention relates to improvements in assemblies which can be used in motor vehicles between the internal combustion engine and the input element of a change-speed transmission to blunt the effects of shocks which develop as a result of fluctuations in the transfer of torque between the engine and the transmission. Still more particularly, the invention relates to improvements in assemblies of the type wherein a first rotary unit receives torque from the engine, a second rotary unit transmits torque to the transmission, the two units are coaxial with and rotatable within limits relative to each other, and the means for transmitting torque between the two units comprises a damper of vibrations and of other undesirable movements. As a rule, or at least in many instances, the damper comprises resilient elements which act in the circumferential direction of the two units and one or more friction generating devices.

Assemblies of the just outlined character are disclosed, for example, in German Offenlequngsschrift No. 29 26 012. The damping action between the two rotary units which can turn within limits with reference to one another is provided by energy storing devices in the form of coil springs and by a friction generating device which is installed to operate in parallel with the coil springs. The coil springs offer a progressively increasing resistance to further angular displacements of the two units with reference to each other from a starting or neutral position. In other words, the coil springs (or at least some of the coil springs) will yield in response to the exertion of a relatively small force when one of the units begins to move from the neutral position, and the resistance increases progressively as the angular displacement of the one unit relative to the other unit increases. The resistance which the friction generating device offers to rotation of the one unit relative to the other unit remains at least substantially constant.

Assemblies embodying the just described damper are designed to operate in such a way that their critical fundamental frequency, namely the critical RPM of the driven and driving parts, develops at a resonance which is below the ignition cycle frequency when the RPM of the engine is at a minimum value, namely the lowest RPM at which the engine is still running. However, when an internal combustion engine is started or turned off, it frequently takes a rather long period of time during which the RPM is within the critical range so that the vibration amplitude of the two units which are rotatable relative to each other increases still further as a result of excitation within such range of rotational speeds. The result is that the resilient elements of the damper between the two units undergo maximum deformation and enable rotation limiting stops on the two units to move into actual contact with each other. Under such circumstances, i.e., when the two stops actually abut against each other, the damper is totally ineffective in that it cannot compensate for or take up any shocks. Therefore, the vehicle which embodies such an assembly is vulnerable to shocks which develop while the two stops are in actual contact with one another due to the absence of any damping or shock absorbing action. This not only affects the comfort of the occupant or occupants of the motor vehicle but also generates pronounced noise. Still further, the shafts, bearings and certain other parts of the engine and transmission in the motor vehicle are likely to undergo substantial damage.

OBJECTS AND SUMMARY OF THE INVENTION

An object of the invention is to provide a novel and improved torsion damping assembly which is particularly effective during starting and/or stoppage of the engine in a motor vehicle.

Another object of the invention is to provide an assembly which can ensure adequate damping of undesirable movements and/or forces during each and every stage of the operation of a motor vehicle and is also highly effective during those stages when the aforediscussed and other conventional torsion damping assemblies are incapable of providing an adequate damping action.

A further object of the invention is to provide a simple, compact and inexpensive torsion damping assembly which can be incorporated in existing motor vehicles in lieu of presently known assemblies as a superior substitute therefor.

A further object of the invention is to provide a torsion damping assembly which can be used to compensate for shocks and variations of torque with a higher degree of efficiency, reliability and predictability than heretofore known assemblies.

An additional object of the invention is to provide a novel and improved method of damping vibrations and/or other undesirable movements between two coaxial parts of a flywheel in a motor vehicle.

A further object of the invention is to provide a novel and improved mode of establishing a torque transmitting connection between the internal combustion engine and the change-speed transmission of a motor vehicle.

Still another object of the invention is to provide novel and improved damper means for use in the above outlined assembly.

Another object of the invention is to provide novel and improved flywheels for use in the torsion damping assembly of the above outlined character.

The invention resides in the provision of an assembly which serves to take up and compensate for torque-induced shocks, especially to take up and compensate for torque which is transmitted between the internal combustion engine and the change-speed transmission of a motor vehicle. The improved assembly comprises coaxial first and second units which are mounted for limited angular movements with reference to each other. The first unit normally receives torque from the engine and the second unit serves to normally transmit torque to the input element of the change-speed transmission. The assembly further comprises a damper which is disposed between the two units and operates to yieldably resist angular movements of the two units relative to each other, and at least one slip clutch which is interposed between the two units and includes opposing means for yieldably resisting a predetermined stage of angular movement of the two units with reference to each other. The damper can comprise a plurality of coil springs or other suitable energy storing elements which act in the circumferential direction of the two units and/or one or more friction generating devices which are interposed between the two units and can be arranged to oppose each and every increment of angular movement of the two units with reference to one another. The damper and the slip clutch preferably operate in series (i.e., they become effective one after the other), and the slip clutch can constitute a multi-stage slip clutch. To this end, the slip clutch can comprise a plurality of stages each of which serves to offer a different resistance to rotation of the two units relative to each other in different angular positions of such units relative to each other. The opposing means of the slip clutch can comprise resilient means in the form of diaphragm springs, leaf springs, coil springs and/or a combination of two or more different types of springs. The resilient means can include one or more springs which are effective to oppose rotation of the two units relative to each other in at least one end portion of the aforementioned stage of angular movement during which the slip clutch is effective.

The first and second units preferably comprise first and second flywheels, and the damper as well as the slip clutch are installed to yieldably resist rotation of the flywheels with reference to each other. In accordance with one presently preferred embodiment, the slip clutch comprises a first component which extends substantially radially inwardly from one of the flywheels and a second component which extends substantially radially from a portion of the other flywheel. One of the components has at least one tooth and the other component has a tooth space into which the tooth extends with a predetermined clearance, as considered in the circumferential direction of the two flywheels. The tooth preferably extends radially inwardly into the space between two radially outwardly extending teeth of the other component. The opposing means of such slip clutch preferably comprises friction generating means which is interposed between the two components to oppose angular movements of such components with reference to each other, as considered in the circumferential direction of the two units, as soon as the clearance between the tooth of the one component and a tooth of the other component is reduced to zero. The friction generating means can comprise at least one friction generating element which is non-rotatably affixed to one of the components and bears against the other component. The friction generating means preferably comprises two friction generating elements which are non-rotatably affixed to one of the components, which flank the other component, and which are urged against the other component. The opposing means can further comprise resilient means (e.g., one or more coil springs) which is or are provided in the tooth space at one or both sides of the tooth of the one component.

One component of the slip clutch can cooperate with or constitute the input component of the damper and the output component of such damper can comprise a pair of coaxial discs which are non-rotatably secured to each other and to one of the flywheels.

In accordance with another embodiment, the opposing means of the slip clutch can comprise at least one lamination provided on the first component of the slip clutch, at least one lamination provided on the second component of the slip clutch and means (e.g., a diaphragm spring) for biasing the laminations against each other. For example, the opposing means can comprise at least one first lamination on one of the components of the slip clutch, at least two second laminations provided on the other component of the slip clutch and flanking the first lamination, and a diaphragm spring which biases the second laminations against the respective sides of the first lamination. In order to obtain a multi-stage slip clutch, the second laminations can be mounted on the other component of the slip clutch with a different degree of play, as considered in the circumferential direction of the two units. Friction between one of the-second laminations and the first lamination can be different from friction between the first lamination and the other second lamination; this can also influence the torque which the slip clutch can transmit between the flywheels of the two units.

In accordance with an additional embodiment of the invention, the slip clutch can comprise means for changing the resistance of the opposing means to angular movements of the two units relative to each other in response to changes in angular positions of the two components of the slip clutch relative to one another. The opposing means of such slip clutch can comprise two neighboring friction generating elements (or simply two neighboring rings or washers without any pronounced friction generating properties) and prestressed resilient means for biasing the two friction generating elements against each other. The means for changing the resistance of such opposing means can comprise means for varying the stress upon the resilient means in response to angular movement of the two units relative to each other. Such varying means can comprise cooperating cam and follower means provided on the two friction generating elements. One of these friction generating elements shares the angular movements of one of the components and the other friction generating element shares the movements of the other component of the slip clutch. The resilient means can comprise a diaphragm spring and the cam and follower means can be provided with ramps which are inclined with reference to a plane extending at right angles to the common axis of the two units.

As a rule, the two-units are rotatable clockwise and counterclockwise relative to each other from a neutral position in which the two friction generating elements of the slip clutch also assume a neutral position. The arrangement is preferably such that the bias of the diaphragm spring is increased irrespective of whether one of the friction generating elements is rotated clockwise or counterclockwise with reference to the other friction generating element or vice versa.

The first unit can receive from the engine nominal torque of a predetermined magnitude, and the magnitude of torque which the slip clutch can transmit between the two flywheels is less (but can also be more) than the predetermined magnitude. For example, the slip clutch can transmit between 8 and 60 percent (preferably between 10 and 35 percent) of the predetermined torque. The magnitude of torque which is transmitted by the slip clutch can be between 5 and 50 percent (preferably between 7 and 30 percent) of the magnitude of torque which is transmitted by the damper. On the other hand, the magnitude of torque which the damper can transmit preferably exceeds the magnitude of nominal torque which the first unit receives from the engine.

The aforementioned stage of angular movement of the two units relative to each other can be between 10 and 50 degrees, preferably between 15 and 35 degrees.

The damper and the slip clutch jointly permit an angular movement of the two units relative to each other through a predetermined angle, and the two components of the slip clutch are preferably movable relative to each other through an angle which is between 60 and 110 percent (most preferably between 80 and 90 percent) of the predetermined angle. The two components of the slip clutch are preferably turnable relative to each other through angles exceeding the maximum angle of clockwise or counterclockwise rotation of one of the flywheels with reference to the other flywheel. Also, the extent of angular displacement of one flywheel with reference to the other flywheel in a clockwise direction can exceed the extent of angular displacement of such one flywheel in a counterclockwise direction, or vice versa.

In the presently preferred torsion damping assembly, the slip clutch is designed to start opposing rotation of the two units relative to each other (either in a clockwise or in a counterclockwise direction) after the one or the other unit leaves its neutral or starting position. During such initial stage or stages of rotation of the two units relative to each other, their mutual angular movements are yieldably resisted by the damper, i.e., by the aforementioned resilient elements of the damper and/or by the friction generating device or devices of the damper.

The slip clutch can constitute a so-called load-responsive clutch whose opposing means begins to frictionally resist (yieldably oppose) further rotation of the two units relative to each other after the two units complete an angular movement from neutral position through a preselected angle which may but need not be the same for rotation in a clockwise and in a counterclockwise direction. Alternatively or in addition to frictional resistance, the slip clutch which constitutes a load-responsive clutch can include means for storing energy after the two units complete a predetermined angular movement in a clockwise or in a counterclockwise direction with reference to one another.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved torsion damping assembly itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** Is a fragmentary axial sectional view of a torsion damping assembly with a slip clutch which embodies one form of the invention;

FIG. **2** is a fragmentary sectional view as seen in the direction of arrows from the line II—II of FIG. **1**;

FIG. **3** is a diagram showing the characteristic damping curve of the assembly which is shown in FIGS. **1** and **2**;

FIG. **4** is a fragmentary elevational view of a second slip clutch;

FIG. **5** is a sectional view as seen in the direction of arrows from the line V—V of FIG. **4**;

FIG. **6** is a fragmentary sectional view similar to that of FIG. **1** or **5** but showing a portion of a third slip clutch; and

FIG. **7** is a sectional view substantially as seen in the direction of arrows from the line VII—VII of FIG. **6**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIGS. **1** and **2**, there is shown a torsion damping assembly **1** which operates between an internal combustion engine **105** and a change-speed transmission **110** in a motor vehicle. The assembly **1** comprises two coaxial units A and B the first of which includes a crankshaft **5** which is driven by the engine **105** and a first flywheel **3**, and the second of which comprises a second flywheel **4** and a friction clutch **7**. The crankshaft **5** is separably affixed to the flywheel **3** by an annulus of bolts **6** or other suitable fasteners, and the housing or cover **11** of the friction clutch **7** is affixed to the flywheel **4**. When the clutch **7** is engaged, its clutch disc or plate **9** transmits torque to the input element **10** of the transmission **110**. The clutch **7** further comprises a pressure plate **8** which normally bears against one of two friction linings **9***a* on the clutch disc **9** and urges the other lining **9***a* into torque-receiving engagement with the flywheel **4**. A diaphragm spring **12** of the friction clutch **7** is tiltable between two seats **12***a* of the cover **11** and normally bears against the peripheral portion of the clutch plate **8** so that the internally splined hub **9***b* of the clutch disc **9** rotates the externally splined portion of the input element **10**. In order to disengage the clutch **7**, i.e., to terminate the transmission of torque between the engine **105** and the transmission **110**, the radially inwardly extending prongs **12***b* of the diaphragm spring **12** must be moved in a direction to the left, as viewed in FIG. **1**, in order to move the radially outermost portion of the diaphragm spring **12** in a direction away from the flywheel **4**. The latter and the flywheel **3** together constitute a composite body or flywheel **2** of the improved torsion damping device **1** and this device further comprises a damper **13** which is installed between and yieldably opposes rotation of the flywheels **3** and **4** relative to each other. In accordance with a feature of the invention, the means for opposing rotation of the flywheels **3** and **4** (i.e., of the units A and B) relative to each other further comprises a second damper in the form of a slip clutch **14** (also known as slip friction clutch) which is disposed radially outwardly of the damper **13**. The damper **13** and the slip clutch **14** operate in series.

A system **15** of bearings is interposed between the flywheels **3** and **4**. In the embodiment of FIGS. **1** and **2**, the system **15** comprises two antifriction ball bearings **16** and **17** which are disposed side by side, as considered in the axial direction of the flywheels **3** and **4**, and which are but need not be identical. The outer race **16***a* of the bearing **16** is installed in a centrally located recess **18** of the flywheel **3** and is compelled to share the angular movements of the latter. The inner race **17***a* of the bearing **17** surrounds and is non-rotatably mounted on a centrally located protuberance **19** of the flywheel **4**. This protuberance centers the smaller-diameter extension **10***a* of the input element **10** and contains a friction bearing for the extension **10***a*. The inner race **16***b* of the bearing **16** is non-rotatably connected to the outer race **17***b* of the bearing **17** by a coupling element **20** which has a cylindrical portion **20***a* surrounded by and non-rotatably secured to the inner race **16***b* and an annular or bell-shaped portion **20***b* which surrounds and is non-rotatably secured to the outer race **17***b*. The two portions **20***a*, **20***b* of the coupling element **20** are disposed side by side, as considered in the axial direction of the flywheels **3** and **4**, and are integrally connected to each other by a washer-like radially extending portion of the coupling element **20**.

In order to ensure that the races **16***b*, **17***b* will rotate with reference to the associated races **16***a*, **17***a* even if the flywheels **3** and **4** perform small or minute oscillatory (back and forth) angular movements relative to each other, the assembly **1** of FIGS. **1** and **2** further comprises two motion transmitting devices **21** and **22** the first of which acts between the cylindrical portion **20***a* and the flywheel **3** and the second of which acts between the flywheel **4** and the annular portion **20**b of the clutch element **20**. The illustrated motion transmitting devices **21** and **22** act not unlike free-wheels and compel the clutch element **20**, and hence the races **16**b and **17**b, to rotate in a single direction with reference to the flywheels **3** and **4**. The direction in which the motion transmitting device **21** blocks rotation of the coupling element **20** relative to the flywheel **3** is the same in which the motion transmitting device **22** blocks rotation of the coupling element **20** with reference to the flywheel **4**. The motion transmitting devices **21** and **22** ensure uniform wear upon the tracks of the races **16**a, **16**b, **17**a, **17**b as well as upon the spherical rolling elements of the bearings **16** and **17** by preventing the rolling elements from simply oscillating back and forth when the nature of operation of the vehicle is such that the flywheels **3** and **4** turn back and forth relative to each other at a high frequency but at a low or very low amplitude (e.g., less than one degree).

The peripheral portion **23** of the flywheel **3** constitutes a circumferentially complete rim which surrounds a chamber **24** for the majority of parts of or the entire composet damper including the damper **13** and slip clutch **14**. That end face (**23**a) of the rim **23** of the flywheel **3** which faces toward the flywheel **4** is adjacent to the input component **25** of the slip clutch **14**, and such input component is affixed to the flywheel **3** by a set of bolts, screws or other suitable fastener means **26**. The input component **25** comprises radially extending sections **25**a and **25**b which are staggered relative to each other, as considered in the axial direction of the flywheels **3**, **4**, and are connected to each other by an axially extending section **25**c located in the chamber **24**. The radially innermost section **25**b of the input component **25** has one or more radially inwardly extending teeth **27** (see particularly FIG. **2**) each of which is disposed in a tooth space **28** of the output component **29** of the slip clutch **14**. The tooth space **28** which is shown in FIG. **2** is machined into or is otherwise formed in the periphery (radially outermost portion) of the output component **29**. The tooth **27** is received in the tooth space **28** with a certain amount of play (**30**+**30**a) which determines the extent to which the components **25** and **29** of the slip clutch **14** are rotatable rotatably relative to each other in the directions which are indicated by the arrows **44** and **45**. In FIG. **2**, the component **25** is located in an intermediate position because the play **30**+**30**a has two portions disposed at the opposite sides of the tooth **27**. The flanks of the tooth **27** are denoted by the reference characters **27**a and **27**b; such flanks face helical springs **52** which are recessed into the tooth flanks **28**a, **28**b of the component **29** and extend in part into the adjacent portions of the tooth space **28** at the respective sides of the tooth **27**. The springs **52** are partially recessed into the flanks **28**a, **28**b of teeth **29**a and **29**b which form part of the component **29** and flank the tooth space **28**.

The means for establishing a yieldable connection between the components **25** and **29** of the slip clutch **14** comprises two friction generating elements **31** and **31**a which flank the components **25**, **29** and are rigidly (non-rotatably) connected to the component **29**. The connecting means comprises specially designed rivets **32** which are affixed to the radially outermost portion of the component **29** of the slip clutch **14**. The friction generating element **31**a is movable axially of the flywheels **3**, **4** toward and away from the element **31** by sliding along the larger-diameter portions **33** of the rivets **32**. The element **31**a stores energy and is or acts not unlike a diaphragm spring which reacts against the heads **32**a of the rivets **32** and bears against the radially extending section **25**b of the component **25**. The element **31** is in frictional engagement with the corresponding sides of both components (**25**, **29**) of the slip clutch **14**. It will be noted that the rivets **32** constitute retainers for the element or diaphragm spring **31**a as well as a means for holding the elements **31** and **31**a against rotation with reference to the components **25**, **29**. The element **31** is held in requisite frictional engagement with the adjacent sides of the components **25**, **29** under the action of the prestressed diaphragm spring **31**a.

In the embodiment of FIGS. **1** and **2**, the components **25**, **29** and the elements **31**, **31**a are made of steel so that the frictional engagement is a metal-to-metal type engagement. However, it is equally possible to resort to organic or inorganic washers or like inserts (for example, between the metallic element **31** and the adjacent side of the section **25**b of the component **25**) in order to generate a different type of friction.

In accordance with a feature of the invention, the slip clutch **14** is integrated into the damper **13**. Thus, the radially innermost portion **34** of the component **29** of the clutch **14** constitutes the input component of the damper **13** and is flanked by two spaced-apart discs **35**, **36** forming part of the unit B. The discs **35**, **36** are rigidly connected to each other and to the flywheel **4** by a set of distancing elements **37** in the form of rivets whose central portions are received with play (as considered in the circumferential direction of the flywheels **3** and **4**) in arcuate slot-shaped openings **34**b of the portion **34**. The latter has windows **34**a which are flanked by windows **35**a and **36**a of the respective discs **35** and **36**. Each of the windows **34**a receives a portion of a coil spring **38** which constitutes one energy storing element of the damper **13** and further extends into the respective windows **35**a and **36**a. The coil springs **38** oppose rotation of the flywheels **3** and **4** relative to each other.

The damper **13** further comprises a friction generating coupling device **39** which yieldably opposes rotation of the flywheels **3** and **4** during each stage of their angular movement relative to one another, i.e., during each and every stage of rotation of the discs **35**, **36** relative to the innermost portion **34** of the output component **29** and/or vice versa. Still further, the damper **13** comprises an additional friction generating coupling device **40** which becomes effective only during a certain stage of angular movement of the flywheel **4** relative to the flywheel **3** in a clockwise or counterclockwise direction, or vice versa.

The friction generating device **39** comprises a ring-shaped friction generating element **39**a which is interposed between the portion **34** and the disc **36**. Furthermore, the friction generating device **39** comprises a diaphragm spring **39**b which reacts against the disc **35** and bears against the portion **34** so as to urge the latter into requisite frictional engagement with the element **39**a as well as to urge the element **39**a into frictional engagement with the disc **36**.

The load-responsive friction generating device **40** comprises a friction ring **41** having axially extending arms **41**a. The arms **41**a extend axially from the radially innermost portion of the ring **41** and through apertures or slots **42** of the portion **34**. The apertures **42** merge into the aforementioned windows **34**a of the portion **34** for the coil springs **38**. The length of the apertures **42**, as considered in the circumferential direction of the flywheels **3** and **4**, is selected in such a way that the parts **41** and **34** can rotate relative to each other only during certain stages of angular movement of the flywheels **3** and **4** with reference to each other. The device **40** further comprises a diaphragm spring **43** whose radially outermost portion reacts against the radially outermost portion of the disc **35** and whose radially innermost portion bears against the tips of the arms **41***a* so that the radially outermost portion of the ring **41** is maintained in frictional engagement with the adjacent side of the disc **36**. The discs **35** and **36** constitute the output component of the damper **13** and determine the extent to which the portion **34** (i.e., the input component of the damper **13**) can turn with reference to the flywheel **4**. As mentioned above, the discs **35** and **36** form part of the unit B because they are rigidly affixed to the flywheel **4**. On the other hand, the portion **34** is rigidly affixed **35** to the flywheel **3** by the fastener means **26**. The flywheels **3**, **4** cannot turn relative to each other when the central portions of the rivets **37** come into abutment with the surfaces at the one or the other end of the respective arcuate slots **34***b* in the portion **34**.

The dimensions of the windows **35***a*, **36***a* in the discs **35**, **36**, the dimensions of the windows **34***a* in the portion **34** of the output component **29**, and the dimensions and characteristics of the coil springs **38** are selected in such a way that the characteristic damping curve of the assembly **1** is a stepped curve, e.g., of the type shown in the diagram of FIG. **3**. In this diagram, the extent of angular displacement of the flywheels **3**, **4** relative to each other is measured along the abscissa and the magnitude of torque which is being transmitted between the two flywheels is measured along the ordinate. The arrow **44** indicates the direction in which the flywheel **3** rotates in order to drive the wheels of the motor vehicle through the medium of the change-speed transmission **110**, and the arrow **45** indicates the direction of rotation when the vehicle is coasting, i.e., when the output element **10** tends to transmit torque to the crankshaft **5**.

It is assumed that the damper **13** is idle (its parts then assume the positions which are shown in FIG. **1**) and that the tooth **27** of the input element **25** of the slip clutch **14** is located in the central or neutral position of FIG. **2**. In such position, the tooth **27** may but need not be located exactly midway between the flanks **28***a*, **28***b* of the neighboring teeth **29***a* and **29***b* on the output component **29** of the slip clutch **14**. If the flywheel **3** or **4** thereupon begins to turn relative to the flywheel **4** or **3** in the direction or arrow **44**, such angular movement is opposed at first by one or more coil springs **38** which constitute the first or weakest constituents of the resilient means including all of the coil springs.**38** of the damper **13**. When the flywheel **3** or **4** (let it be assumed here that the flywheel **3** rotates relative to the flywheel **4**) completes an angular movement through the angle A' (FIG. **3**) and continues to turn in the direction of arrow **44**, the weakest coil spring or springs **38** of the damper **13** are assisted by the next set of (stronger) coils springs **38** so that the damper **13** then offers a more pronounced resistance to rotation of the flywheel **3** relative to the flywheel **4**. When the flywheel **3** completes an angular movement through the angles A' and B', the coil springs **38** of the first two sets of such springs in the damper **13** jointly transmit a torque which matches the torque **46** that can be transmitted by the slip clutch **14**. Thus, if the flywheel **3** continues to turn with reference to the flywheel **4** in the direction of arrow **44** beyond the angle A'+B', the components **25**, **29** of the slip clutch **14** move relative to each other until the flank **27***b* of the tooth **27** shown in FIG. **2** engages with the flank **28***b* of the tooth **29***b* on the component **29**. This terminates the ability of the input and output components **25**, **29** of the slip clutch **14** to move relative to each other. As the flywheel **3** continues to turn in the direction of arrow **44** through the angle C of FIG. **3**, the components **25** and **29** rotate as a unit because the tooth **27** of FIG. **2** continues to bear against the tooth **29***b*. When the angular movement of the flywheel **3** through the angle A'+B'+C is completed, the coil springs **38** of the first two sets undergo additional compression while the flywheel **3** turns through the angle D. The coil spring or springs **38** of the third set of such coil springs in the damper **13** store energy while the flywheel **3** turns through the angle E, i.e., rotation of the flywheel **3** relative to the flywheel **4** in the direction of arrow **44** is then opposed by three sets of coil springs **38**. Deformation of (i.e., storing of energy by) the third set of coil springs **38** is terminated when the flywheel **3** completes the angle A'+B'+C+D+E; at such time, the median portions of the distancing elements **37** come into engagement with the arcuate (concave) end portions of surfaces bounding the respective arcuate slots **34***b* in the portion **34** of the output component **29** of the slip clutch **14**. From there on, the flywheels **3** and **4** rotate as a unit if the flywheel **3** continues to turn in the direction of arrow **44**. The torque which the damper **13** then transmits between the flywheels **3** and **4** is shown in FIG. **3** at **47**. Such torque preferably somewhat exceeds the nominal torque which is transmitted by the internal combustion engine **105** so that the distancing elements **37** are likely to strike against the aforementioned arcuate end portions of surfaces bounding the respective slots **34***b* of the portion **34** (input component of the damper **13**) only when the direction of load changes and the magnitude of transmitted torque exceeds the anticipated magnitude.

During return movement of the parts of the damper **13** to their normal or starting positions of FIG. **1** (such starting positions have been shifted in the direction of arrow **44** through the angle C due to angular movement of the components **25**, **29** of the slip clutch **14** relative to each other and are indicated in FIG. **3** by the reference character **48**), the coil springs **38** of the damper **13** dissipate energy during an angular movement of the flywheel **3** relative to the flywheel **4** in the direction of arrow **45** through an angle F. The angle F equals the sum of angles A', B', D and E.- The angle B'+D is the angle which is covered by the flywheel **3** while the coil spring or coil springs **38** of the second set of such springs in the damper **13** dissipate energy. If the flywheel **3** continues to turn relative to the flywheel **4** in the direction of arrow **45** beyond the new neutral-or starting position **48**, the coil spring or coil springs **38** of the first set begin to store energy while the flywheel **3** turns through an angle G. When the angular movement through the angle G (in the direction of arrow **45**) is completed, the parts **34** and **35**, **36** cooperate to stress the coil spring or coil springs **38** of the second set so that the angular movement of the flywheel **3** in the direction of arrow **45** is then opposed by two sets of coil springs **38**. Such springs continue to store energy until the torque which is generated thereby reaches that value at which the coil springs of the first and second sets overcome the force (**46***a*) with which the components **25** and **29** of the slip clutch **14** oppose rotation relative to each other. At such time, the components **25** and **29** of the clutch **14** start to turn with reference to one another and this angular movement of the parts **25**, **29** relative to one another is terminated when the flanks **27***a* of the teeth **27** on the input component **25** engage the flanks **28***a* of the respective teeth **29***a* on the output component **29** of the slip clutch **14**. Such angular movement of the components **25**, **29** of the slip clutch **14** relative to each other is completed while the flywheel **3** turns in the direction of arrow **45** through an angle I. The reference character H denotes in FIG. **3** that angle which is covered by the flywheel **3** in the direction of arrow **45** while the coil spring or coil springs **38** of the second set of such springs in the damper **13** undergo additional compression before the components **25**, **29** of the slip clutch **14** begin to slide relative to each other.

When the flanks **27***a* of the teeth **27** engage the flanks **28***a* of the respective teeth **29***a* on the output component **29** of the slip clutch **14**, and if the flywheel **3** continues to turn in the direction of arrow **45**, the coil spring or coil springs **38** of the second set of such springs in the damper **13** undergo additional compression while the flywheel **3** turns through an additional angle K, and such additional compression of the second set of coil springs is terminated when the distancing elements **37** strike the respective end portions of surfaces bounding the corresponding arcuate slots **34***b* in the input element **34** of the damper **13**. The magnitude of torque which is transmitted by the damper **13** at such time is shown at **49** in the right-hand portion of FIG. **3**.

If the direction of rotation of the flywheel **3** relative to the flywheel **4** is thereupon reversed (from the direction of the arrow **45** to the direction of arrow **44**), the coil springs **38** of the damper **13** dissipate energy while the flywheel **3** turns through an angle L at which time the parts of the damper **13** reassume their starting or neutral positions (indicated by the reference character **50**). Such neutral positions are shifted from the neutral positions denoted by the character **48** of FIG. **3** by the angle I, i.e., an angle corresponding to that which is covered by the flywheel **3** in the direction of arrow **45** while the components **25** and **29** of the slip clutch **14** move relative to one another. The components **25**, **29** of the slip clutch **14** again begin to move relative to each other at the point **51** in the diagram of FIG. **3**.

As can be seen in FIG. **3**, the torque **47** (when the angular movement of the flywheel **3** relative to the flywheel **4** in the direction of arrow **44** is terminated by the distancing elements **37** and the surfaces bounding the respective slots **34***b*) exceeds the torque **49** which is transmitted by the flywheel **3** when the latter completes its angular movement relative to the flywheel **4** in the direction of arrow **45**. In the illustrated embodiment, the torque **46** at which the clutch **14** begins to slip equals or approximates 20% of the maximum torque **47** which the damper **13** can transmit in the direction of arrow **44**.

FIG. **3** further shows that the angle I (during which the components **25**, **29** of the slip clutch **14** turn relative to each other) exceeds the angle F or L, i.e., the angle through which the input and output components **34** and **35**, **36** of the damper **13** can turn relative to each other in the directions of arrows **44** and **45**, respectively. In the embodiment of FIGS. **1** and **2**, the angle L is smaller than the angle F, i.e., the angle through which the flywheel **3** turns relative to the flywheel **4** in the direction of arrow **44** while the components **34** and **35**, **36** of the damper **13** turn relative to each other is greater than the angle which is covered by the flywheel **3** in the direction of arrow **45** while the components **34** and **35**, **36** of the damper **13** turn relative to each other.

FIG. **3** does not show the frictional hysteresis which is caused by the friction generating devices **39** and **40** of the damper **13**. The moments which are generated by the devices **39** and **40** are superimposed upon the moments which are generated by the coil springs **38** of the damper **13** in those regions (i.e., during movement of the flywheel **3** relative to the flywheel **4** through those angles) in which the devices **39** and **40** are operative.

The coil springs **52** of FIG. **2** are optional. Such springs need not necessarily be mounted on the teeth **29***a*, **29***b* of the output component **29** of the slip clutch **14**. For example, the springs **52** can be mounted on the teeth **27** or one thereof can be mounted on the tooth **27** while the other spring **52** is mounted on the corresponding tooth **29***a* or **29***b*. The purpose of the springs **52** is to prevent the teeth **27**, **29***a* or **27**, **29***b* from striking against each other with a pronounced force. The effect of the springs **52** is not shown in the diagram of FIG. **3**. The resistance which the springs **52** offer to certain stages of further rotation of the components **25** and **29** relative to each other is superimposed upon the slip torque of the clutch **14**.

An advantage of the assembly **1** is that its constituents can be put together or taken apart in a simple and time saving manner. Thus, the flywheel **3** can be affixed to the crankshaft **5** by bolts **6** in a first step, and the thus assembled unit A is then connected with the preassembled unit B as well as with certain other parts by the fastener means **26**. The flywheel **4** can be readily assembled with the damper **13**, slip clutch **14** and friction clutch **7** preparatory to attachment to the flywheel **3** by fastener means **26**. The clutch disc **9** is then already centered between the pressure plate **8** of the friction clutch **7** and the flywheel **4**. The system **15** of bearings **16** and **17** can be mounted on the flywheel **3** before the latter is connected with the flywheel **4** by fastener means **26**. Alternatively, the system **15** can be assembled with the flywheel **4** before the latter is attached to the flywheel **3**.

It has been found that, by the simple expedient of conforming the slip clutch **14** to the vibration characteristics of the engine **105** (prime mover) and to the characteristics of the damper **13**, such slip clutch can effectively prevent excessive vibrations or oscillations of the units A and B by destroying requisite amounts of surplus energy.

The characteristics (such as stiffness and/or the initial stress) of the coil springs **52** can be readily selected in such a way that these springs perform a highly desirable shock absorbing action when the tooth **27** of FIG. **2** approaches the tooth **29***a* or **29***b*. Such springs also prevent the tooth **27** from rebounding on impact against the tooth **29***a* or **29***b*, i.e., the springs **52** can be constructed and mounted to prevent direct contact between such teeth.

The slip clutch **14** can be used with particular advantage in motor vehicles wherein the space between the crankshaft **5** of the engine **105** and the input element **10** of the change-speed transmission **110** is at a premium. This is due to the fact that the components **25**, **29**, the friction generating elements **31**, **31***a* occupy very little room, as considered in the axial direction of the flywheels **3** and **4**.

As explained in connection with FIG. **3**, the magnitude of nominal torque which the engine **105** transmits to the unit A can be less than the maximum torque (shown at **47**) which can be transmitted by the damper **13**. However, the maximum torque (**46**) which the slip clutch **14** can transmit is preferably a relatively small fraction (between 8 and 60 percent, most preferably between 10 and 35 percent) of nominal torque which the engine **105** transmits to the unit A.

The maximum torque (**46**) which the slip clutch **14** transmits between the flywheels **3** and **4** is preferably a small fraction (between 5 and 50 percent and most preferably between 7 and 30 percent) of the maximum resistance (**47**) which the damper **13** can offer to rotation of the units A and B with reference to each other. Such design of the slip clutch **14** ensures that the assembly **1** can be constructed with a view to ensure that only the damper **13** opposes rotation of the flywheel **3** relative to the flywheel **4** (or vice versa) in a clockwise or counterclockwise direction from a neutral position before the slip clutch becomes operative (as at C during rotation in the direction of arrow **44** in FIG. **3**). The components **25** and **29** of the clutch **14** begin to slip relative to each other when the torque of the already stressed (first and second sets of) coil springs **38** of the damper **13** suffices to overcome the resistance of the means **31**, **31***a* which oppose rotation of the components **25** and **29** relative to each other. The coil springs **38** of the damper **13** undergo additional stressing (as at D and E in FIG. **3**) when the components **25** and **29** can no longer turn relative to one another. As already explained in connection with FIG. **3**, the situation is analogous when the flywheel **3** proceeds to turn in the direction of arrow **45** (after having completed its angular movement in the direction of arrow **44** with reference to the flywheel **4**), i.e., the coil springs **38** of the damper **13** dissipate some energy before the components **25, 29** begin to turn relative to each other and, when the angular movement of the components **25, 29** relative to each other is completed, the springs **38** again dissipate energy (as at K).

In some instances, the slip torque of the clutch **14** can exceed the nominal torque of the engine **105**.

It has been found that the slip clutch **14** will operate quite satisfactorily if the components **25** and **29** can turn relative to each other through angles of between 10 and 50 degrees, preferably between 15 and 35 degrees. The angle of maximum angular displacement of the components **25, 29** relative to each other can be between 60 and 110 percent (preferably between 80 and 90 percent of the maximum angle of angular displacement of the flywheels **3** and **4** relative to each other). Also, the maximum angle through which the components **25** and **29** can turn relative to each other preferably exceeds the maximum angle through which the flywheel **3** or **4** can turn clockwise or counterclockwise from its starting or neutral position. As already mentioned above, the angle through which the flywheel **3** or **4** can turn in the direction of arrow **44** (when the engine **105** drives the input element **10** of the change-speed transmission **110**) preferably exceeds the angle through which the flywheel **3** or **4** can turn in the direction of arrow **45** (coasting). The slip clutch can more readily conform its operation to the vibration characteristics of the engine **105** (i.e., of the prime mover) if at least a portion (**52**) of the opposing means (**31**, **31***a*, **52**) of the slip clutch is designed to start to oppose rotation of the units A and B relative to each other after the flywheel **3** or **4** already completes a certain stage of its angular movement from the starting or neutral position. As also mentioned above, the slip clutch is preferably a load-dependent clutch which comprises means (FIGS. **4–5**) for offering frictional resistance or means (**52**) for storing energy only after the flywheel **3** or **4** has already completed a certain angular movement from the starting position.

FIGS. **4** and **5** illustrate a portion of a modified torsion damping assembly wherein the components **125** and **129** of the slip clutch **114** constitutes a set of several coaxial slip clutches); cooperate in a different way. The input component **125** of the clutch **114** comprises a plate-like carrier **53** which axially movably supports several disc-shaped friction generating elements in the form of laminations of lamellae **54**, **55** and **56**. The radially outermost portions of the laminations **54**, **55** and **56** respectively carry radially extending teeth **54***a*, **55***a* and **56***a* received in sockets or cutouts **53***a* provided in the inner edge face of the plate-like carrier **53** so as to prevent rotation of the laminations **54–56** with reference to the input component **125**.

The output component **129** of the slip clutch **114** also carries a set of axially shiftable laminations **57, 58, 59** which alternate with the laminations **54, 55,** and **56**, as considered in the axial direction of the slip clutch **114**. The radially innermost portions of the laminations **57, 58** and **59** are respectively formed with profiled portions here shown as teeth **57***a*, **58***a*, **59***a* which are adjacent the central openings of the respective laminations and extend into complementary profiled portions including sockets or cutouts **129***a* in the peripheral surface of the component **129**.

The carrier **53** of the input component **125** further supports an annular washer-like stop **60** which is disposed at one side of the clutch **114** (adjacent to the laminations **56** and **59**). The other side of the carrier **53** supports a group of radially extending leaf springs **61** which are secured to the carrier **53** by rivets **62** and whose radially innermost portions bear upon the adjacent side of the lamination **54** so that the entire package of alternating laminations **54, 57, 55, 58, 56, 59** is urged axially against the stop **60** and the neighboring laminations are urged against each other. The rivets **62** preferably constitute the means for securing the stop **60** to the carrier **53** of the input component **125**. The laminations **54** to **59** cooperate with each other, with **5** the leaf springs **61** and with the stop **60** to oppose angular movements of the components **125** and **129** of the slip clutch **114** relative to each other.

As can be seen in FIG. **4**, the width of the teeth **57***a*, **58***a*, **59***a* on the respective laminations **57, 58, 59** (as considered in the circumferential direction of the components **125** and **129**) is not uniform. Thus, each of the laminations **57, 58, 59** can turn with reference to the component **129** to a different extent. This ensures that the friction generating means **54–61** between the components **125** and **129** of the slip clutch **114** operate in several successive steps or stages. In other words, the moment of friction between the components **125** and **129** can vary in response to progressive increase of the angle through which the components **125** and **129** are moved angularly relative to each other.

FIG. **5** shows that the laminations **54** to **56** of the input component **125** are in direct frictional engagement with the laminations **57, 58** and **59**. However, it is equally possible to employ in the slip clutch **114** one or more organic or inorganic friction rings which are interposed between certain laminations or between all of the neighboring laminations and/or between the laminations **59** and the stop **60** and/or between the lamination **54** and the leaf springs **61** to thereby influence the friction between the components **125** and **129**. In this manner, the slip clutch **114** can be caused to more accurately meet the specifications in a particular type of torsion damping assembly.

The multi-stage or composite slip clutch **114** of FIGS. **4** and **5** is especially suited to conform to the vibration characteristics of the engine and to the characteristics of the associated damper. As explained above, the resistance which the clutch **114** offers to rotation of the two units relative to each other increases with increasing angular displacement of the components **125, 129** relative to each other.

FIGS. **6** and **7** illustrate a third slip clutch **214** with an input component **225** and an output component **229**. The latter comprises a disc-shaped member **64** and a profiled member **63** which is made of sheet metal and is secured to the disc-shaped member **64** by rivets **163**. The profiled member **63** has a substantially Z-shaped cross-sectional outline and its radially outermost portion **63***b* is integral with an axially extending annular portion **63***a*. The latter forms with the disc-shaped member **64** a trough for a friction washer **65** which is adjacent to the inner side of the member **64** and is remote from the radially extending portion **63***b*. The left-hand side of the washer **65**, as viewed in FIG. **6**, is in contact with the respective side of the input component **125**. The space between the input component **125** and the portion **63***b* of the profiled member **63** of the output component **129** accommodates a friction washer **66** which is non-rotatably affixed to the component **125** as well as a washer **67** and a friction generating element **68** having prongs **68***a* extending in the axial direction of the slip clutch **214** and into the adjacent cutouts **63***b*' of the portion **63***b*. A diaphragm spring **69** reacts against the inner side of the portion **63***b* and bears against the friction generating element **68**. Thus, the diaphragm spring **69** urges the part **68** against the part **67** which urges the part **66** and the component **225** against the part **65** so that the latter is urged against the disc-shaped member **64** of the output component **229**. The arms or prongs **68***a* of the friction generating element **68** hold the latter against rotation with reference to the profiled member **63**, i.e., with reference to the output component **229**.

As can be seen in FIG. **7**, the washers **66** and **67** are formed with axially extending complementary male and female profiles or detent portions. Such detent portions form cam and follower means having ramps **70** and **71**. Thus, and starting from the angular positions of the components **225**, **229** which are shown in FIG. **7**, rotation of such components relative to one another in either direction from the neutral positions of FIG. **7** entails an axial movement of the washers **66**, **67** away from each other to thereby change the bias of the diaphragm spring **69** in dependency on the angular positions of the components **225**, **229** with reference to each other. This, in turn, entails a change in the slip torque of the clutch **214**. The slip torque increases as the stress upon the diaphragm spring **69** increases. In the embodiment of FIGS. **6** and **7**, the slip torque increases regardless of whether the washer **67** is rotated in a clockwise or in a counterclockwise direction, as viewed in FIG. **7**, because the cam and follower means which is defined by the washers **66**, **67** is shown in the neutral or median position. The slope of the ramp **70** can be different from that of the ramp **71** so that the slip torque increases at a first rate then the washer **66** or **67** is rotated in first direction and at a different second rate when the washer **66** or **67** is rotated in a second direction counter to the first direction. The planes of the ramps **70**, **71** are inclined with reference to a plane which is normal to the common axis of the flywheels (not shown in FIGS. **6** and **7**).

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic and specific aspects of our contribution to the art and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the appended claims.

We claim:

1. Apparatus for absorbing fluctuations of torque transmitted between a first flywheel connectable with a rotary output element of an engine for rotation about a first axis and a second flywheel rotatable relative to the first flywheel and connectable to a transmission by an engageable and disengageable clutch, comprising means for opposing rotation of the flywheels relative to each other, including energy storing members acting circumferentially of the flywheels; a bearing interposed between the flywheels and having a second axis coinciding with said first axis; and means for connecting the first flywheel to the output element of the engine including a plurality of fasteners having portions extending through openings provided therefor in the first flywheel, the first flywheel having a first side confronting the engine and a second side facing away from the engine, said bearing including a radially outermost portion disposed at a first radial distance from said axes and the openings of the first flywheel being disposed at a greater second radial distance from said axes.

2. The apparatus of claim **1**, wherein said fasteners include shanks extending through the respective openings and beyond the first side of the first flywheel and heads adjacent the second side of the first flywheel.

3. The apparatus of claim **1**, further comprising a second bearing for an input shaft of the transmission, said second bearing being located radially inwardly of said bearing which is interposed between the flywheels.

4. The apparatus of claim **1**, wherein said opposing means further comprises a slip friction clutch.

5. The apparatus of claim **1**, further comprising means for determining the maximum torque which can be transmitted between said first and second flywheels.

6. The apparatus of claim **1**, wherein said opposing means further comprises a friction generating device.

7. The apparatus of claim **1**, wherein said opposing means further comprises a load-responsive friction generating device.

8. The apparatus of claim **1**, wherein said opposing means further comprises a damper and a slip friction clutch in series with said damper.

9. The apparatus of claim **1**, wherein said opposing means comprises a damper having at least one resilient stage including said energy storing members.

10. The apparatus of claim **1**, wherein said opposing means further comprises a slip clutch including input and output components, said components being rotatable relative to each other about said axes within a predetermined angle.

11. The apparatus of claim **1**, wherein said bearing includes at least one antifriction bearing having rolling elements.

12. The apparatus of claim **1**, wherein said opposing means includes a damper comprising said energy storing members, a hysteresis component, and means for limiting the transmission of torque between the flywheels, said damper and said hysteresis component and said limiting means being disposed between the flywheels.

13. The apparatus of claim **1**, wherein at least one of said flywheels is rotatable relative to the other of said flywheels from a starting position and against the opposition of said energy storing members.

14. The apparatus of claim **1**, wherein said second flywheel has a friction surface engageable by a clutch plate of said clutch.

15. The apparatus of claim **1**, wherein at least one of said flywheels has a portion which directly receives at least a portion of said bearing.

16. The apparatus of claim **1**, wherein at least one of said flywheels has a tubular extension receiving at least a portion of said bearing and having an axis coinciding with said first and second axes.

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